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STEEL MAKING MATERIAL RECYCLING SYSTEM

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Technical Field

The present invention relates to steel processing material, methods of preparing such materials and methods of manufacturing steel using such materials. The materials and methods of the invention allow the use of iron-bearing by-product material in the steel industry.

Background of the Invention

In the steel industry, especially when melting scrap steel in an electric arc furnace, solid waste material, commonly referred to as Furnace Exhaust Material (FEM), from the post combustion exhaust chamber is generated. Typically, an exhaust system is used to direct this material to a bag house. The FEM typically is very high in iron (Fe) content. Some of this material, called post combustion material (PCM), comprises particles that are too heavy or too large to be exhausted to the bag house. Such material can be gravity fed from the combustion chamber to a drop out box or similar arrangement. Thus, FEM is generated from the post combustion chamber drop out box as PCM or is evacuated on to the bag house as bag house dust. The iron content from either location is typically about 40% by weight. However, the

iron content can vary from about 20% to about 75% by weight. These materials can also have about 15-25% by weight moisture, about 20% by weight of material similar in content to the slag foaming material currently added to the furnace, and up to about 5% by weight of other metals and oxides. The slag foaming material can include calcium and magnesium oxides, iron, carbon and/or manganese.

The slag foaming materials are originally introduced into the steel making process to develop a foamy slag that, among other things, creates a chemical environment in a heat of steel where the exchange of oxygen and other unwanted materials in the steel can occur. However, due to the extreme temperatures, various chemical reactions, and the necessary environmental exhausting of furnace gases, some of the slag foaming materials are undesirably exhausted into the flume or exhaust chamber. Similarly, some of the iron in the steel and in the slag can also be exhausted into the chamber. These materials typically agglomerate or otherwise combine to create dust or larger particles within the exhaust chamber.

The combustion chamber or the post combustion chamber duct work of a steel manufacturing assemblies offer water cooled. Water from leaks, sprays or any other source may travel by gravity through the post combustion chamber and wet the post combustion material. Post combustion material removed from the drop out box is typically stored in an outside yard for further disposition. Either in the drop out box or in the yard, the PCM can absorb a great deal of moisture from the atmosphere, rain or other sources. The moisture content of wet PCM is usually significantly above 2% and usually is greater than 6% and, more typically, is about 15-20%, all by weight. However, some processes may avoid the moisture pickup thus delivering a dry PCM, confirming less than about 2% by weight.

Currently, PCM undergoes an expensive secondary reclamation processes to recover the heavy metals or is sent to landfills for disposal.

The use of secondary reclamation processes to recover the heavy metals are generally very expensive. Currently such processes require expensive equipment, extensive handling of the material, and the use of chemical additives. After processing, the material may still not be desirable in many applications. U. S. Patent No. 5,738,694, to Ford, dislcoses an example of the secondary processing of similar material. Ford discloses iron rich material waste products, such as electric arc furnace dust, formed with an organic binder into discrete shapes, such as briquettes and/or other solid shapes. The shapes can then be used in iron and steel making processes and may allow recovery of the iron and heavy metals values in the waste product.

Some manufacturers have found it more economical to send the PCM to landfills. The cost of reclaiming the heavy metals can be much greater than the cost of landfilling and the decrease in steel quality and life of the furnace is too great to justify merely reintroducing the PCM back into the process.

Other iron-bearing waste materials may be generated throughout the steel making process. As previously discussed, bag house dust is continually made in the steel making process. Steel makers continue to struggle with cost effective means of processing, selling or otherwise eliminating bag house dust. The secondary processes in steel making also create a significant amount of iron-bearing waste materials, including for example, scale generated at the caster or rolling mill. Other sources of iron wastes include iron fines generated by the recovery of rolling solution in a cold rolling mill, the cleaning of steel in a galvanizing line or other cleaning/finishing processes. A further source of iron waste is a high purity iron oxide recovered from spent pickle liquor of a pickling process. All of these sources of by-product iron materials create a dilemma for the steel maker in dealing with disposal of these materials.

Summary of the Invention

In one embodiment, the invention relates to steel processing materials. The steel processing materials comprise a dried post combustion material (PCM) and a slag foaming material.

In another embodiment, the invention is directed to a method of preparing the steel processing material. The methods comprise recovering PCM from a steel making process and drying the PCM. In a further embodiment, the methods of preparing the steel processing material comprise recovering dry PCM from a steel making process and mixing the PCM with a slag foaming material.

In another embodiment, the invention is directed to methods of manufacturing steel. The methods comprise melting a first heat of steel, whereon the heat has a liquid steel portion and a foamy slag portion. The melting generates PCM. The PCM is dried and added into a second heat of steel.

In yet another embodiment of the current invention a steel processing material comprises a recycled material and a slag foaming material.

Advantages and novel features of the present invention will become further apparent to those skilled in the art from the following detailed description, which simply illustrates various modes and examples contemplated for carrying out the invention. As can be realized, the invention is capable of other different aspects, all without departing from the invention. Accordingly, the drawings and descriptions are illustrative in nature and not restrictive.

Brief Description of the Drawings

While the specification concludes with claims particularly pointing out and distinctly claiming the present invention, it is believed that the same can be better

understood from the following description, taken in conjunction with the accompanying drawing, in which:

Fig. 1 illustrates a schematic view of an exemplary embodiment of a PCM reclamation facility in accordance with the present invention.

Detailed Description of Exemplary Embodiments

Reference can now be made in detail to various exemplary embodiments of the invention, some of which are also illustrated in the accompanying drawing. Throughout the specification and claims, all ports and percentages are by weight unless otherwise specified.

Solid waste material such as Furnace Exhaust Material (FEM) is generated by the steel making process. The current invention contemplates removing some of the moisture content and/or otherwise recycling FEM material back into the process. The FEM is typically generated as particles collected from the drop out box, known as Post Combustion Material (PCM), or dust from the bag house, as described above. Different plants or operations in the steel industry may use different terms other than drop out box particles or bag house dust, however, the term "post combustion material" as used in this invention should be understood to cover any iron-bearing material from the exhaust of a steel making furnace. Such furnaces may include a basic oxygen furnace, an electric arc furnace, a degasser, or any similar furnace creating solid material from the exhaust chamber. The post combustion material as used in the current invention further includes iron-bearing solid waste materials such as iron fines, scale, iron oxide from pickle liquor, or other similar steel making materials as known to those skilled in the art.

If PCM is directly reintroduced back into the steel making process, several problems can occur, for example, because the moisture is broken down into its

elemental components (H_2 and O_2). Excess hydrogen in the steel can decrease the castability and increase porosity of the steel. The increased oxygen both increases melting time, requiring more energy for heat, and produces "dirty" steel. Reactions from both the hydrogen and oxygen can also be detrimental to the life of the furnace. Additional processing costs may also be incurred, for example, by increased cost and time at a treatment facility such as a ladle furnace. Further, the moisture alone can cause safety concerns if the PCM is submerged in liquid steel because the expansion of the moisture, from water to steam, can cause an explosion.

Reintroducing the PCM back into the process may also cause the foamy slag characteristics of the furnace to be changed because the moisture of the PCM decreases the effectiveness of the foamy slag. The chemical reactions between the steel and slag may be decreased and poor coverage of the steel by the foamy slag may occur. Nitrogen pickup may also increase as poor coverage of the foamy slag allows air to contact the liquid steel.

In one embodiment of the current invention, wet PCM, typically at about 15 to 25% by weight water content, is obtained from the steel making furnace, for example in particle form from a drop out box. The wet PCM is dried to remove at least a portion of the moisture. For example, in one embodiment, the PCM is air dried to about 6-15% by weight water content. The PCM can be sorted to facilitate further drying, other processing, or subsequent use of the material. In one embodiment the sorting is accomplished by screening to obtain one or more fractions of desired average particle size. In a further embodiment, the PCM is sorted to obtain a fraction having a maximum particle size, for example of about 1 inch, more specifically of about 3/4 inch, even more specifically of about 5/16 inch. The sorted material can then be subjected to further processing, and in one embodiment is dried further to about 2% by weight water content. The PCM, now referred to as dried PCM, can be reintroduced into the steel making process. For example, the dried PCM can be added

by charging buckets, direct charging, or otherwise reintroduced into the steel making process using techniques known to those skilled in the art.

The further drying may be achieved using any apparatus or method known in the art. For example, the drying may be conducted using a rotary dryer, common in the steel industry, or using a screw auger dryer. The screw auger dryer can heat the PCM by, for example, induction heaters, gas-fired heaters or other such heating systems. Use of a screw auger dryer can be beneficial in that an auger is relatively inexpensive as compared with a rotary dryer, the screw auger dryer can be installed in a relatively small space, and installation time for a screw auger dryer can be a few weeks compared to several months for a rotary dryer. A screw auger with an induction drier or other type of electric operated drier may also be more environmentally friendly as compared with a rotary drier such as one requiring natural gas or fuel oil or one having a fluid bed. The induction dryer typically does not need preheat time, does not give off hazardous gasses such as NOX, and allows for tighter temperature control. The tighter the temperature control, the less the likelihood of gases evolving from the material being dried. Thus, the screw auger drier may also be useful where environmental conditions need tight control, such as where an increase in gasses are objectionable and/or may complicate permitting issues.

However, the rotary drier may operate more efficiently. If time and space are not critical, a rotary drier could be advantageous.

The sorting step preceding the mechanical drying may vary according to the type of dryer, the material processed, i.e., the degree or type of agglomeration or otherwise fused properties of the material, and/or the contamination of the material. Contamination may occur, for example, where large pieces of scrap mix with the PCM because scrap and PCM are often stored adjacent one another. Such scrap could damage a dryer or limit further use of the PCM. In one embodiment using a rotary dryer, the sorting ahead of a rotary dryer may only need to be to a particle size of 3",

or the sorting may be eliminated. However, an embodiment using an auger may require screening, sorting, for example, to a maximum of about ¾ of an inch particle size or less. Other embodiments are contemplated wherein no screening step is required due to the inherent small particle size and lack of contamination.

In some steel making processes, the PCM may remain dry throughout generation and recovery. However, even without the moisture content problem, adding the PCM back into the steel making process may be difficult. For example, injecting PCM may be difficult because of the limited size of an injection gun compared to the size of some PCM particles and other scrap metal which may tend to become mixed with the PCM. Also, injected PCM may displace slag foaming materials inhibiting necessary chemical reaction between the steel and the slag.

Additional embodiments may include PCM that has not absorbed moisture and is below 2% moisture content in the drop box. Such "dry PCM" does not need to undergo a further drying process and may be screened and/or mixed with slag foaming materials for injection into the steel making process, as will be discussed.

According to another embodiment of the current invention, the dried PCM can be sorted further. This may include screening to give a size that will not block or clog an injection gun as is commonly used to add slag foaming material in an electric arc furnace. This screening may be to about 5/16 of an inch, i.e., to the size of the slag foaming material. Once the PCM has been sized to about 5/16 of an inch, it can proceed, for example, via a bucket elevator, into a first PCM container such as a silo. Once in a first container, the PCM can be discharged into a second container such as a super sack or a truck. The PCM can be mixed concurrently with the slag foaming material to make a modified slag foaming material. The modified slag foaming material can be added into the top of an arc furnace, usually by an injection gun, to create a foamy slag on the top of the molten bath of steel.

In one embodiment of the current invention, the modified slag foaming material is injected after slag has foamed on a heat of steel. Such an embodiment typically has an environment that is hot and oxygen rich enough to cause the generally endothermic materials in the PCM to become exothermic, thus generating heat and reducing power usage. The oxygen may create energy, for example, by oxidizing some of the iron in the PCM. The high temperature may also melt the iron from the PCM. Further, both the carbon from the slag foaming material and other metals in the PCM may reduce the oxidized iron, further allowing recovery of the iron into the liquid steel. Such oxidation and reduction reactions are known to those skilled in the art and may be reviewed by the Gibb's free energy equations and diagrams. An example of generating heat and reducing power will be discussed later.

A typical slag foaming material may consist of about 90% coal and about 10% dolomitic stone. In one embodiment of the current invention, a modified slag foaming material, that is, a slag foaming material with PCM added, may comprise about 10 to 20% PCM, about 70 to 80% coal and about 8 to 12% dolomitic stone. However, according to the principles of the current invention, a modified slag foaming material may comprise from about 0% up to about 30% by weight PCM, and behave efficiently in the steel making process.

In additional embodiments, other slag foaming materials such as any other carbon and/or low sulfur products, and/or materials including calcium and magnesium oxides, iron, carbon, and manganese, as known to those skilled in the art, may be mixed with the PCM.

Fig. 1 illustrates one exemplary embodiment of a facility 30 for the processing of the PCM in accordance with the invention. The facility 30 includes a first receiving hopper 40 for loading of PCM generated by the steel making process. The material can be processed from the first receiving hopper 40 to a first screen 42. In one embodiment, the first screen 42 comprises a 5' by 7' double decked scalping

screen. The first screen 42 screens the PCM to obtain a fraction having a desired maximum particle size, for example, of about 3/4 inch. The screened PCM fraction of the desired size is delivered via a discharge conveyer 44 to a first screen fraction or stockpile 46. Material too large to be screened by the first screen 42 may be stockpiled, for example, in a screened "overs" stockpile 70, or otherwise processed to reduce its size, or discarded. Material from the first screened fraction stockpile 46 is transported, for example by a front end loader, a conveyor or the like to a second receiving hopper 50. The PCM is next fed from the second receiving hopper 50 to screw auger 52. The auger 52 can be a heated, dewatering auger in certain embodiments. For example, the auger may include induction heaters to heat the PCM and evaporate the water content of the material. In one embodiment, the PCM is heated to reduce the water content to less than about 2%. In other embodiments of the current invention the auger 52 can be replaced by a conventional rotary dryer, or any other dryer effective to reduce the water content of the PCM.

Exiting the auger 52, the material is transported by a feed conveyor 54 to a second screen 56. In one embodiment, the second screen 56 comprises a 4' by 8' single deck scalping screen. The second screen 56 screens the PCM to obtain a fraction having a maximum particle size about 1/4 inch. The screened PCM fraction is transported, for example, by a bucket elevator 58, to a first storage silo 60. In the embodiment of Fig. 1, a second storage silo 62 is adjacent the storage silo 60. The second storage silo 62 may contain any of a variety of slag foaming materials such as anthracitic coal, coke, or any other carbon and/or any other low sulfur product known to those skilled in the art for use in a steel making process. The slag foaming material may additionally include materials such as dolomite or spar. Further, the two storage silos can have a single load out spout (not shown). The single load out spout may allow for mixing of the two materials concurrent with addition of the materials to a container such as a transport truck.

Other sources of high iron-bearing steel waste material may be similarly recycled. Such materials include bag house dust, scale and iron fines. In alternative embodiments, driy high iron-bearing steel waste materials may be all be stored in a single silo, in combinations of silos, or each in individual silos. In one embodiment of the current invention, the bag house dust is stored in a storage silo similar to the PCM. The bag house dust is mixed directly with the slag foaming material. A single load out spout may also allow the mixing of the bag house dust with the slag foaming material concurrently as the materials are added to a transport truck. Since bag house dust typically has a moisture content that is less than 2%, a drying process is typically not necessary. Also, because bag house dust is usually small in size, less than 5/16 inch, and is typically clean or free of other (larger) contaminants, it may not need to be sorted. However, should the bag house dust have a high moisture content greater than about 2%, or be agglomerated in particle size too large to inject, the drying and/or screening process, as described above for the PCM, may also be used.

Scale, as generated from steel processing, such as caster scale or mill scale, may be treated similarly. However, since such scale may have a higher concentration of iron oxide content, the concentration of scale to slag foaming material may be adjusted. Also, scale is typically high in moisture content. High moisture content scale should be dried as described above with respect to the PCM. That is, the scale may be dried, for example, by a rotary dryer or screw auger dryer to about 2% by weight or less water content. Further, the scale may be screened before and after drying as needed to reach the previously discussed particle sizes. Upon injection and between the scale contained in the modified slag foaming material and the high temperature slag should possibly be exothermic because the Fe_3O_5 will be oxidized to Fe_2O_3.

Other iron-bearing materials, such as those generated by the steel cold finishing processes, may also be mixed with slag foaming material to provide a steel

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processing material. For example, the iron fines recovered from cold mill rolling solution or temper mill rolling solution or from cleaning processes, such as a cleaning process in galvanizing line, may also be used. Again, these materials may be wet or of sufficiently large size that drying and/or screening may be necessary. Drying, screening, and/or mixing processes as discussed above may be employed. These materials are typical of high Fe content and may behave similar to PCM in that the oxidation of the iron is an exothermic reaction. Also, a relatively high purity iron oxide may be recovered from spent pickle liquor. This material, though possibly already dried by a roaster, may become wet or otherwise increase to moisture content. This material, too, may be screened, dried, and/or mixed according to the methods previously discussed for use with the PCM. Depending on the particular iron oxide materials available to cause an exothermic reaction with the high temperature slag.

An exempary comparison of batch recovered a charging PCM in charge buckets, drying and mixing PCM with slag foaming materials will now be discussed. Approximately 1,000 pounds of PCM is batch charged into a 200 ton heat of steel. Nitrogen increases in the steel by 15 parts per million (PPM). Further, when PCM is directly charged in the bucket, the kilowatt hour per scrap ton (KWH/ton) increases by about 37 KWH/ton. However, when the PCM is dried and mixed with slag foaming material in an amount of about 95% by weight slag foaming material and 5% by weight PCM, an increase in KWH is not seen and the KWH actually appears to decrease. This may be due to oxidation of iron and manganese. Also, there was no increased nitrogen in the steel and the FeO weight percent in the slag did not increase.

In this example, the dried and mixed PCM contains about 45% by weight of iron and about 1.7% by weight of manganese. This equates to about 144 pounds of iron and 5.4 pounds of manganese. One hundred forty-four pounds of iron, when oxidized during the melting process from approximately 76° F to 2,900° F would create about 85 kilowatt hours, if reacted 100% to completion. However, at only 50%

reaction, 43 kilowatt hours would be produced. Similarly, 5.4 pounds of manganese reacted with oxygen from 76° F to 2,900° F generates about 5 KWH, when reacted completely or 2.5 KWH when reacted 50%.

In the exemplary comparison, batch charging recovered PCM increases both power usage and the time necessary to melt a heat. These factors, along with possible decreased quality in steel, make recharging PCM directly very expensive, especially when considering that newly recovered PCM may increase power usage by approximately 8%. Alternatively, the dried and mixed PCM may decrease power usage by approximately 10%.

Additional embodiments of the current invention are directed to methods of manufacturing steel. In one embodiment of this method, a first heat of steel is melted. A slag foaming material may also be added to the heat. A liquid steel portion and a foamy slag portion are developed. The melting of the heat evolves both some of the steel and the foamy slag as furnace exhaust materials. The furnace exhaust materials may be exhausted toward a bag house. Some of the materials (PCM) may be too heavy or large or may be washed away from the exhaust by a water stream and may not be exhausted to the bag house. A drop out box is typically provided to accumulate these materials.

In an embodiment of this method, the PCM may become wet from leaks, sprays, rain or any other source inside or external to the exhaust duct or to the drop out box. Thus, the PCM may need drying in accordance with the methods discussed above. Drying may be achieved by a screw auger, a rotary dryer, or the like. In other alternative embodiments, the PCM may not be wet, but rather a moisture content less than about 2% by weight, and may proceed directly to further processing steps.

A method of sorting the PCM before drying, as previously discussed, may be used to properly size the particles for the drying process. A method of further sorting before storing, mixing, or injecting of the PCM may be used as previously discussed.

Once dried and sorted as needed, the PCM is added into a second heat of steel. The PCM may be added by injection with an injection gun, mixing with another material such as a slag foaming material and then injected or added in batch.

As PCM undergoes the process of multiple iterations of being generated, recovered and added back into the steel making process, a build up in the PCM of heavy metals such as zinc and lead may occur. In one embodiment made in accordance with the current invention, a limit or set point, such as 0.0010% by weight of lead, is set for heavy metal concentration in the PCM. Once the limit is met, the PCM is removed from the iterative process. For example, a clean steel producer may generate PCM that has heavy metals well below a threshold as set by regulation or the producer. Each time PCM is added back into a heat and recovered again, the concentration of these heavy metals increases. As the concentration of heavy metals in the PCM increases to the set point, typically less than the threshold, the PCM may be removed from the iterative process and sent to a reclamation process. The more concentrated heavy metals may offset the cost of reclamation, should improve the efficiency of the reclamation process and may reduce the steel makers need to land fill the PCM. However, in an additional embodiment, the PCM with a high concentration of heavy metals may be sent to a landfill. Similar embodiments may be maintained for bag house dust of any other iron bearing material.

Some of the beneficial characteristics of this invention may include increased liquid steel yield, decreased energy cost, decreased land fill requirements, and decreased shipping and handling of waste material. Thus the invention both decreases cost for the steel industry and improves the environment.

Having shown and described the preferred embodiments of the present invention, further adaptations to the post combustion material recycling system of the present invention as described herein can be accomplished by appropriate modifications by one of ordinary skill in the art without departing from the scope of the present invention. Several of these potential modifications and alternatives have been mentioned, and others can be apparent to those skilled in the art. For example, while exemplary embodiments of the inventive system and process have been discussed for illustrative purposes, it should be understood that the elements described can be constantly updated and approved by technological advances. Similarly, as described, the process of this invention could be applied with any steel processing waste material substantially bearing iron. Accordingly, the scope of the present invention should be considered in terms of the following claims and is understood not to be limited to the details of structure, operation or process steps as shown and described in this specification and drawing.